Armed Forces College of Medicine

AFCM

Hemodynamics

Physical Laws Governing Blood Flow

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Lecturer of Physiology

Cardio-Pulmonary Physiology

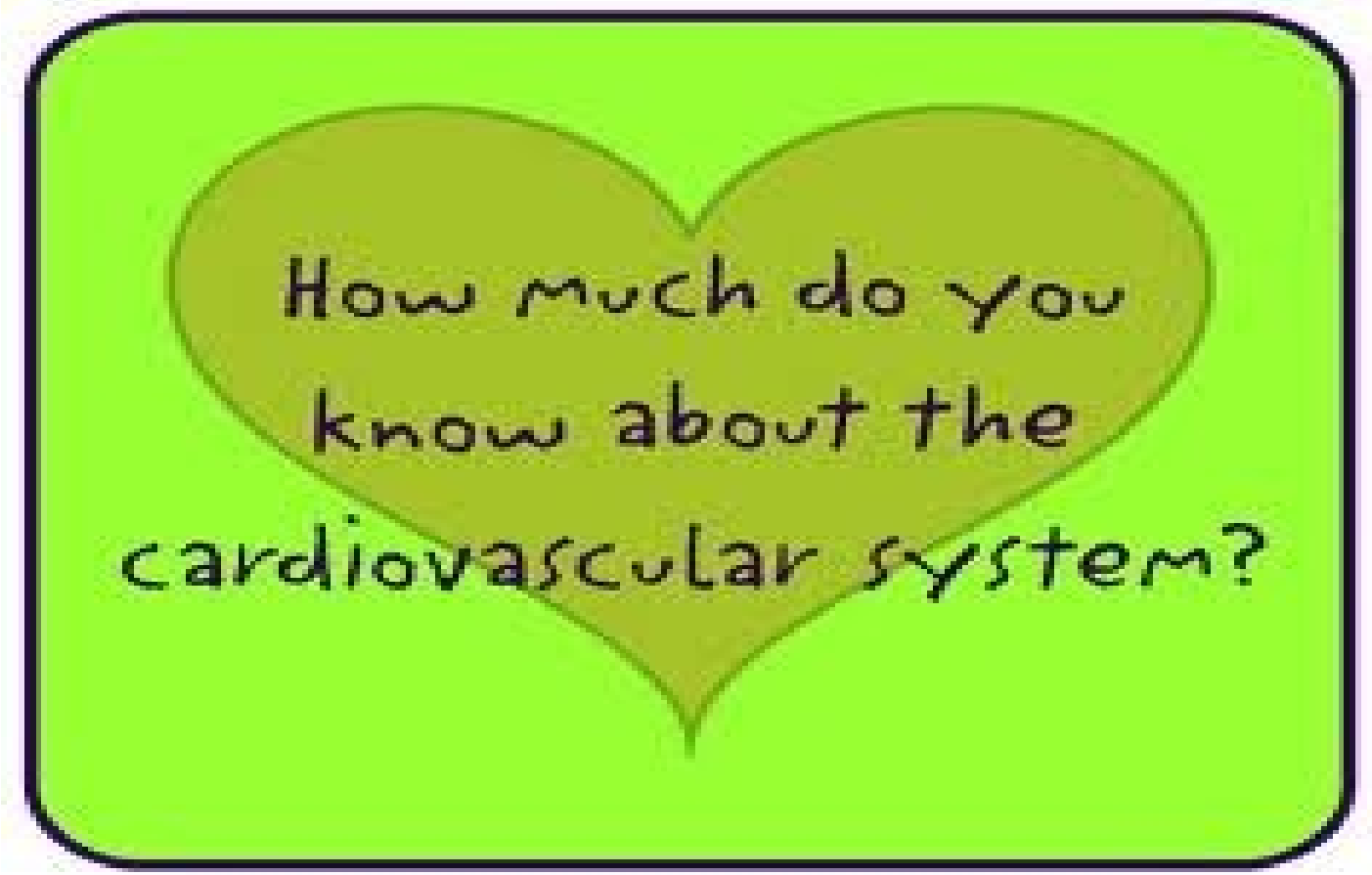
Lecture 9: Circulatory Hemodynamics (1)

INTENDED LEARNING OBJECTIVES (ILO

By the end of this lecture the student will be able to:

1. Identify the major mechanisms in control vascular resistance and blood flow distribution.
2. Describe the relationship among blood flow, blood pressure, and vascular resistance.
3. Explain the relative changes in flow through the vascular system caused by changes in radius, blood viscosity, and pressure difference.
4. Apply the information studied in this section to solve a clinical problem or explain clinical case.

Introduction



Functions of the CVS

- **Provide oxygen and nutrients to body tissue**
- **Remove waste products from body tissue**
- **Temperature regulation**
- **Defense mechanism**

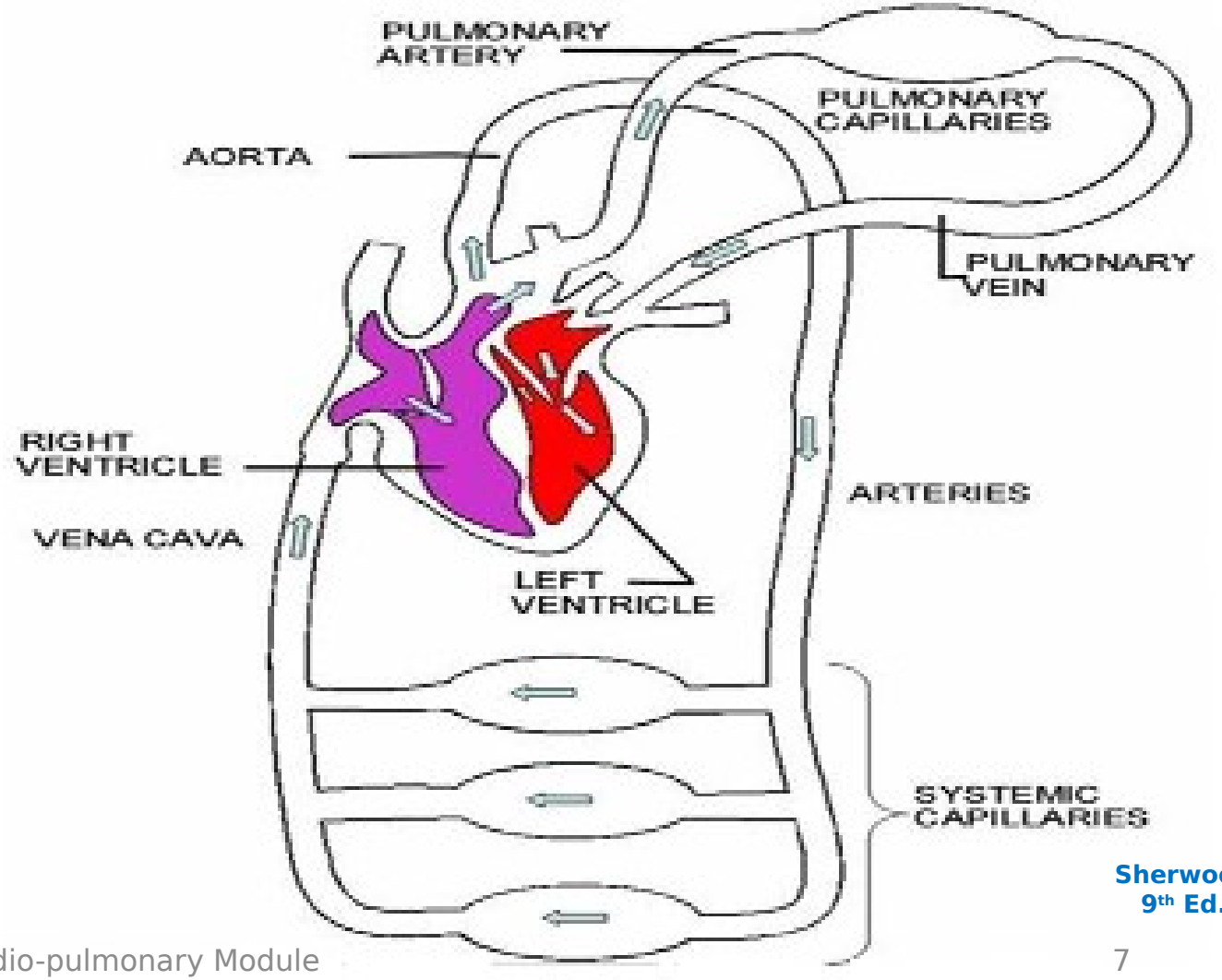
General Arrangement of the CVS

CVS

1- Heart

2- Blood vessels

- a- Arteries
- b- Veins
- c- Capillaries



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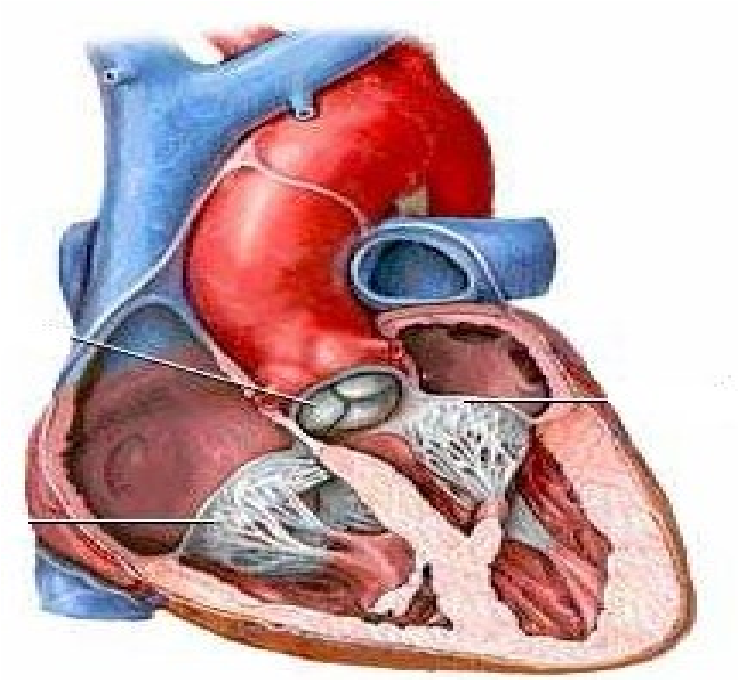
Heart

Veins



Arteries

Capillaries

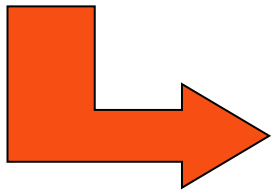
Blood Vessels

I- Arteries

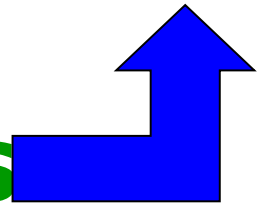
1- Large size
2- Medium size
3- Small size
4- Arterioles

III- Veins

1- Large size
2- Medium size
3- Small size
4- Venules



II- Capillaries



Blood Flow

Definition:

- **It is the amount of blood that passes through certain vessel / unit time (L/min)**
- **The total blood flow in the circulation = 5L/min (Cardiac Output, COP)**
- **Blood always flow from areas of high pressure to areas of low pressure**

Measurement:

1- Direct

2- Indirect

Blood Flow

***Calculation*:**

- **Flow can be calculated according to Ohm's Law**
- **Flow (F) = Pressure gradient (ΔP) / Resistance (R)**

$$F = \Delta P / R$$

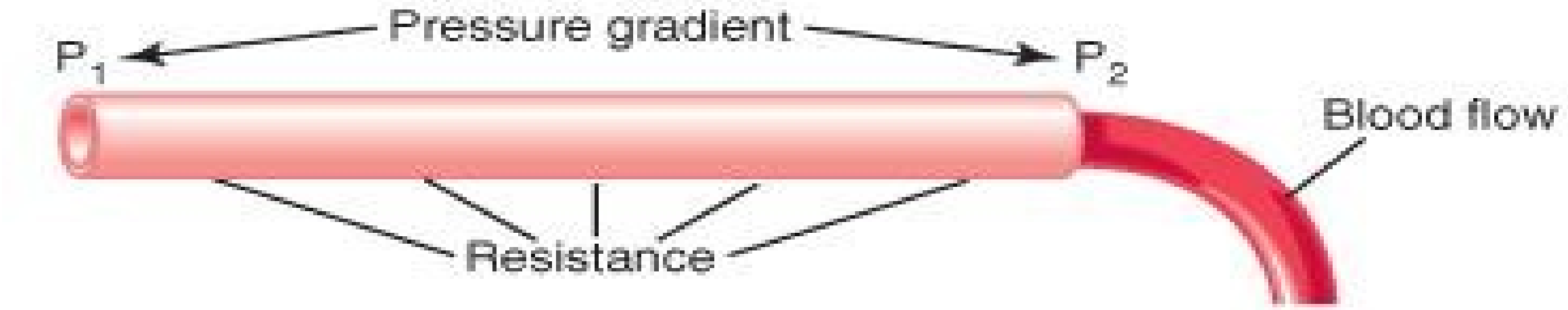
What is the driving force for blood to flow within the CVS?

Relations between: Flow, Pressure & Resistance

I- *Pressure gradient* (ΔP):

- ΔP Is the pressure gradient between the 2 ends of the vessel
- Flow is directly proportionate to ΔP
- Pressure is generated by the ***Heart***
- ↑ Blood pressure ↑ ↑ Flow ***by:***
  1- ↑ force that pushes the blood forward
  2- Distend the vessels

$$F = \Delta P\ (P_1 - P_2) \ / \ R$$



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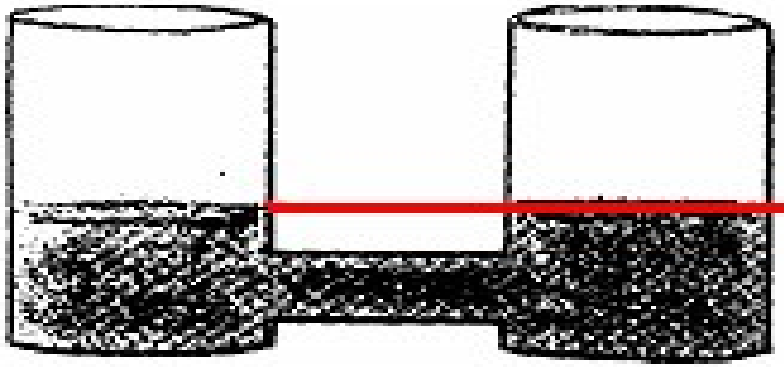
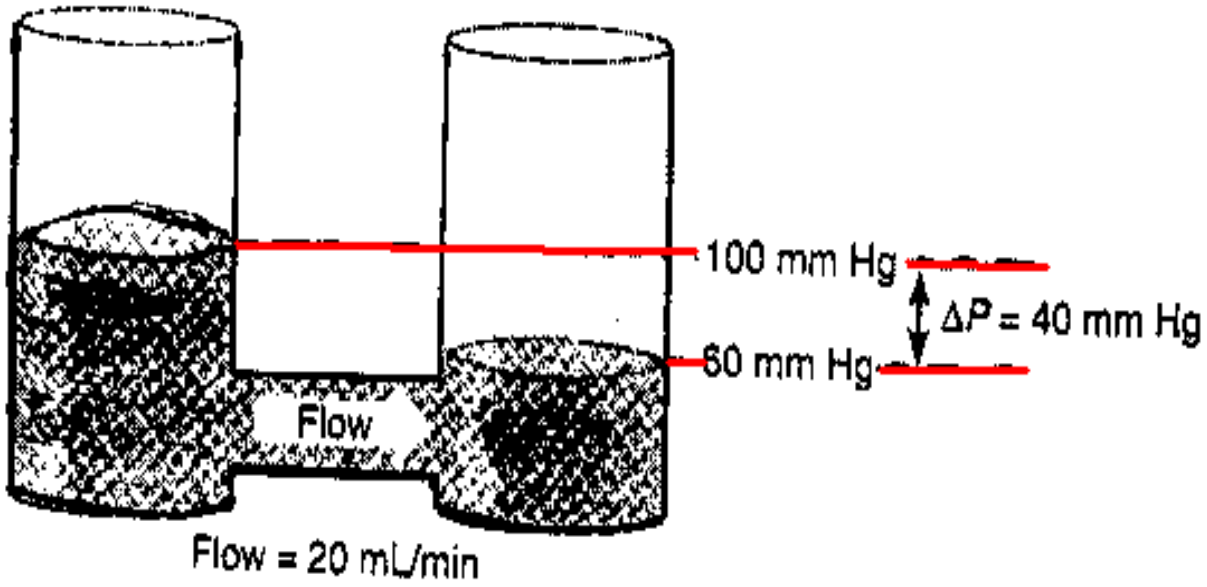
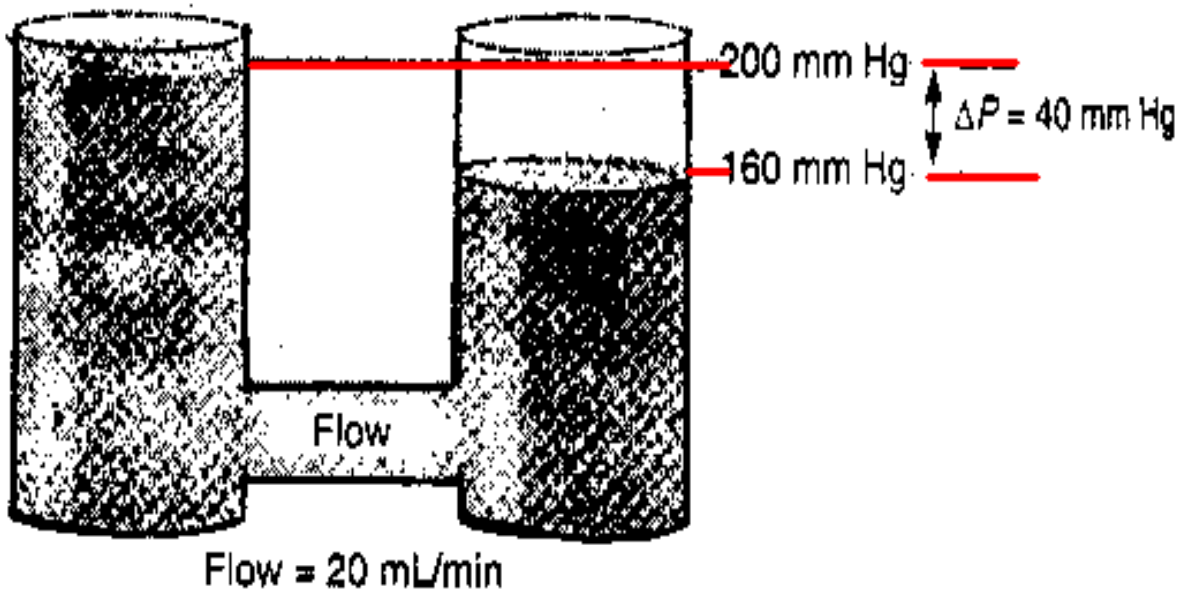
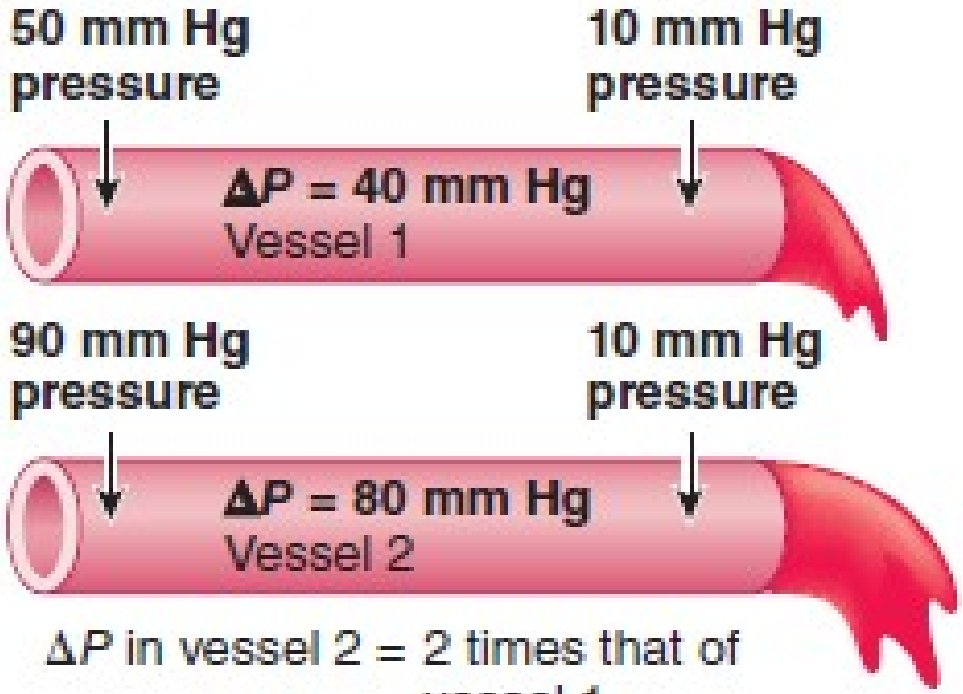


ΔP = 0 mmHg

Flow = 0





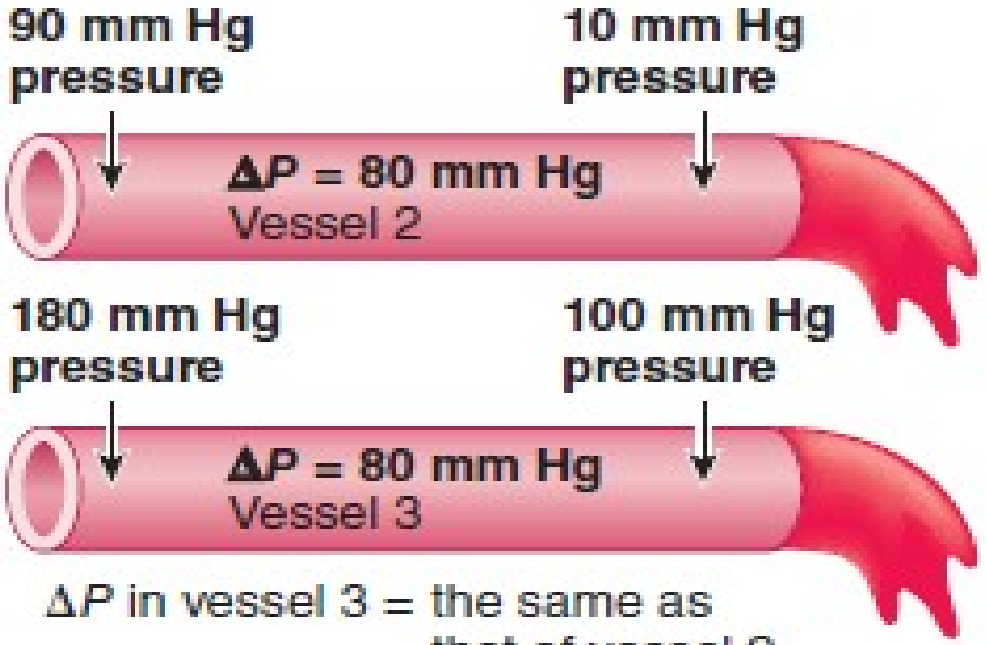


ΔP in vessel 2 = 2 times that of vessel 1

Flow in vessel 2 = 2 times that of vessel 1

Flow ∝ ΔP

(a) Comparison of flow rate in vessels with a different ΔP



ΔP in vessel 3 = the same as that of vessel 2, despite the larger absolute values

Flow in vessel 3 = the same as that of vessel 2

Flow ∝ ΔP

(b) Comparison of flow rate in vessels with the same ΔP

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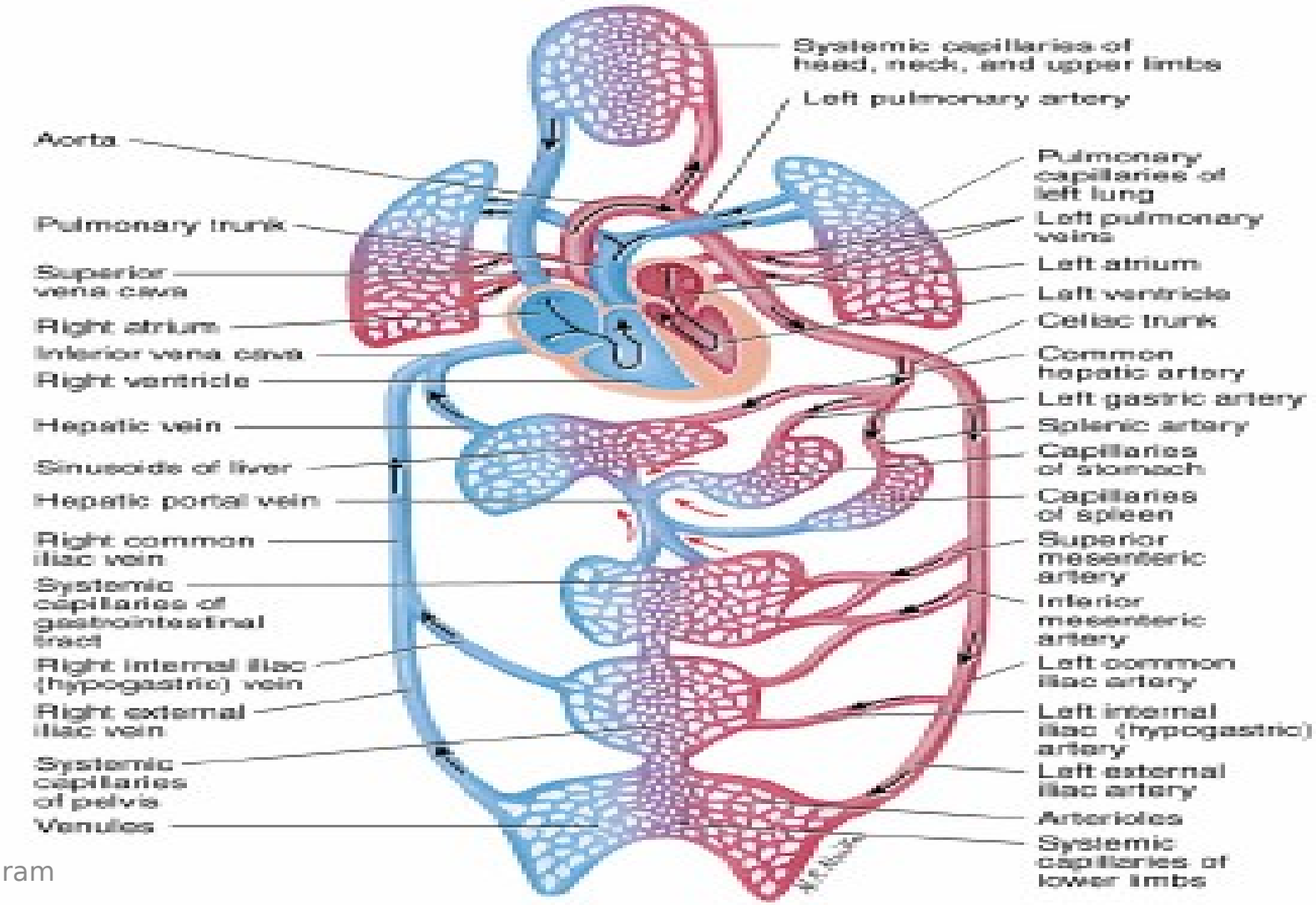
Δ P in the CVS



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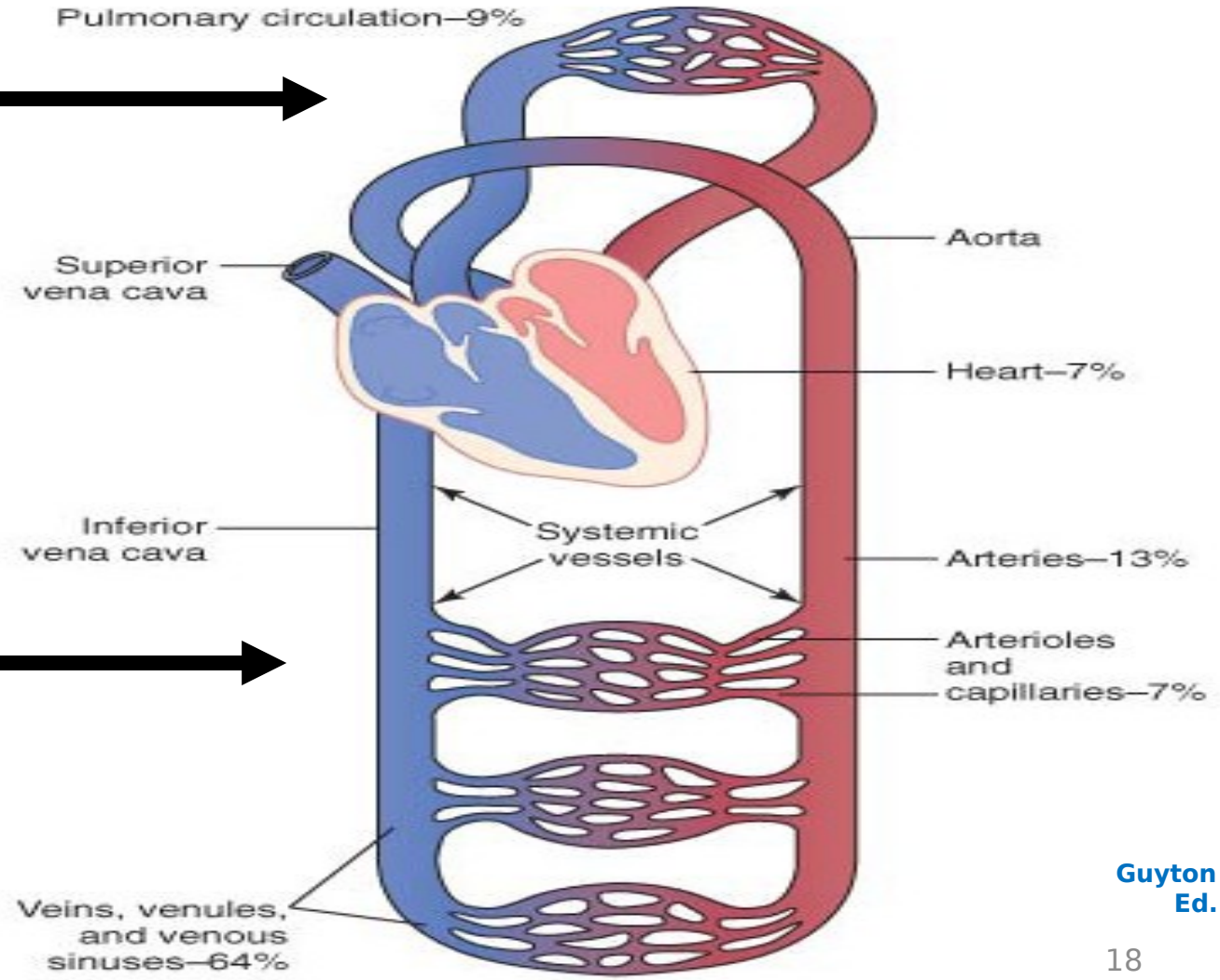
Δ P in the CVS

Pulmonary
Circulation

Systemic
Circulation



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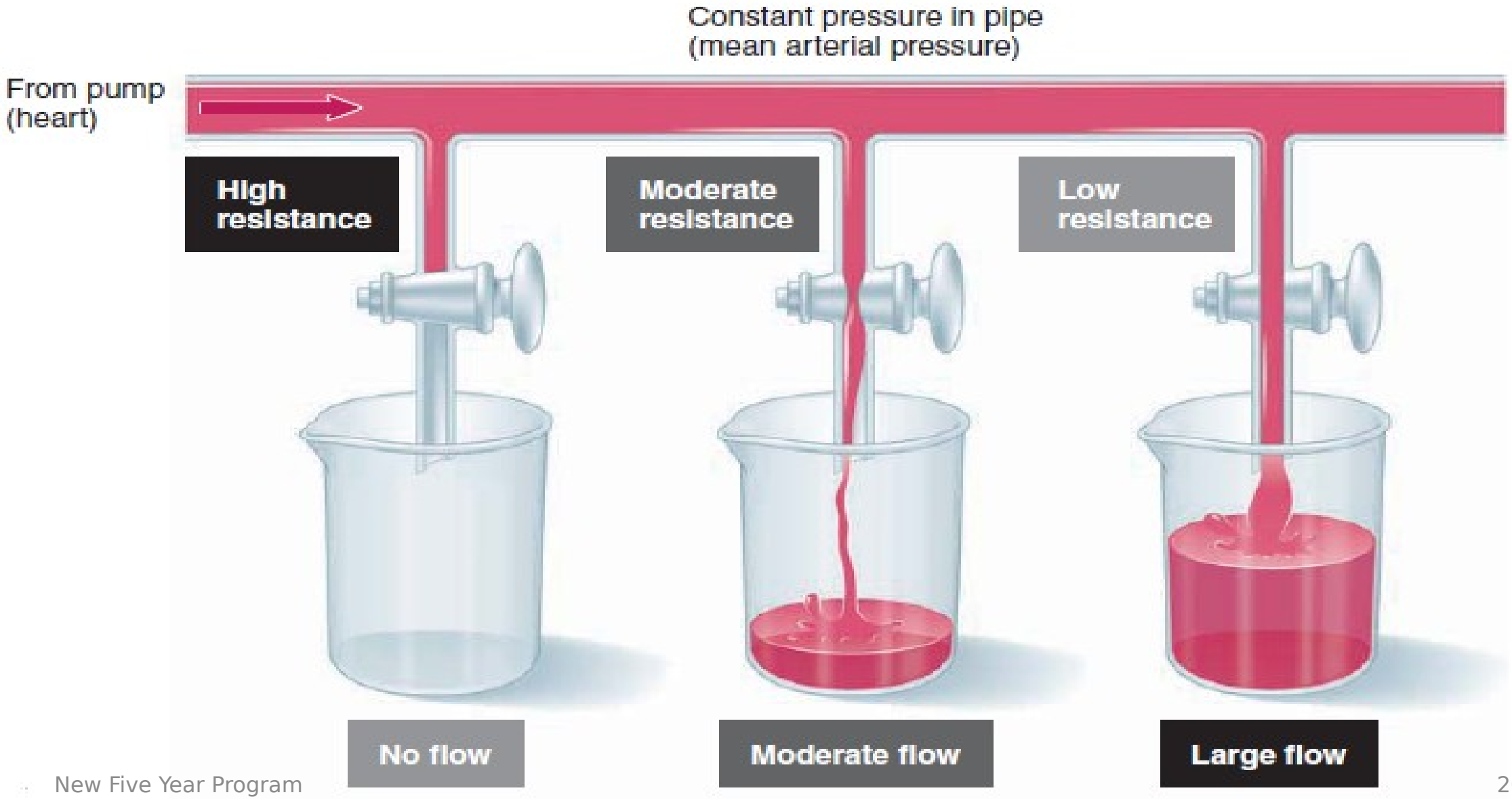
Relations between: Flow, Pressure & Resistance

II- *Resistance* (R):

- **R** Is the impedance to blood flow in a vessel
- Resistance results from :
  1- Frictional forces between the blood & the wall of the vessel
  2- Frictional forces between the blood molecules
- Resistance depends on:
  1- Physical properties of the vessel (*length*, *radius*)
  2- Physical properties the blood (*viscosity*)



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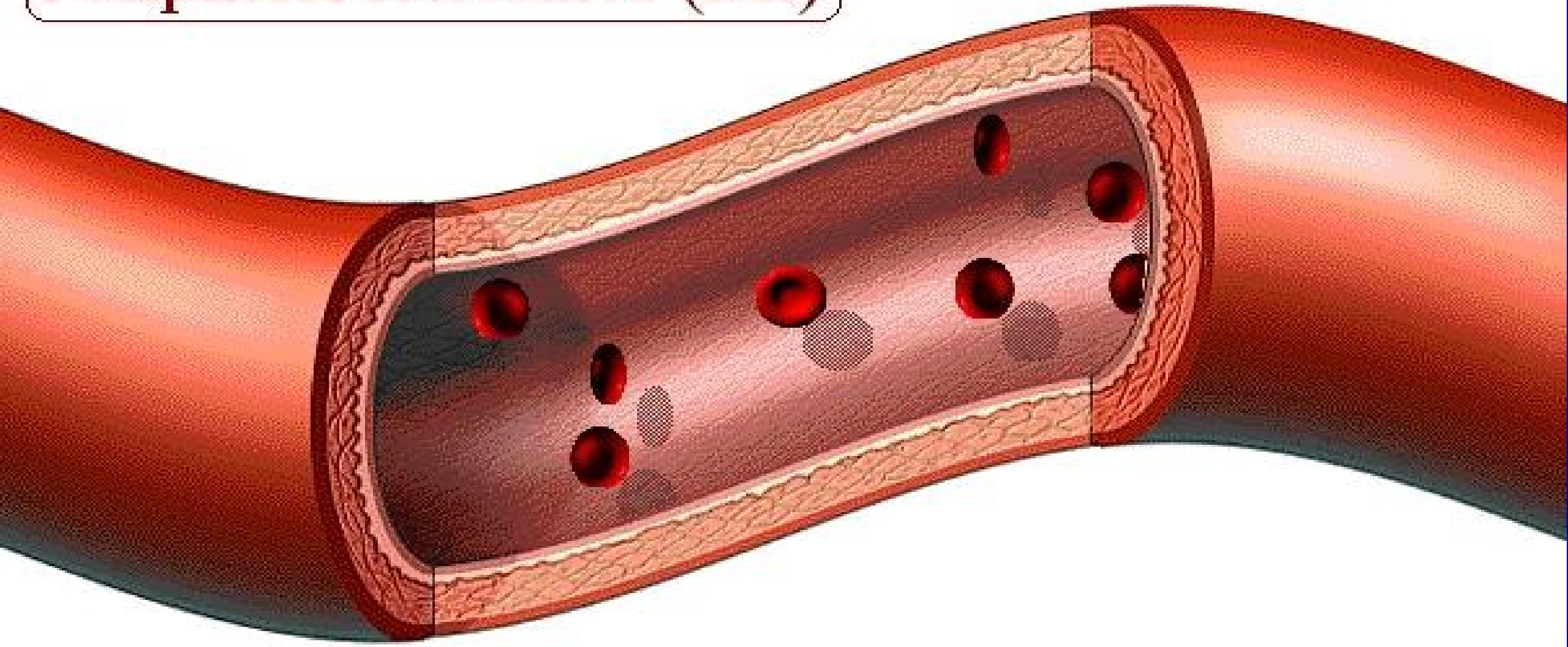
Peripheral resistance (PR)



Resistance

- **R can be calculated according to Poiseuille's Law**

$$R = \frac{8\,L\,\eta}{\pi\,r^4}$$

L : Length of the vessel

η : Viscosity of the blood

r : Radius of the vessel

π : Constant (22/7)

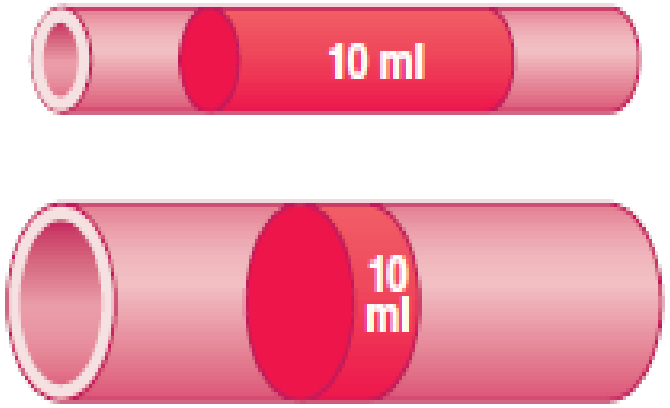
Factors Affecting Resistance

1- Length of the vessel:

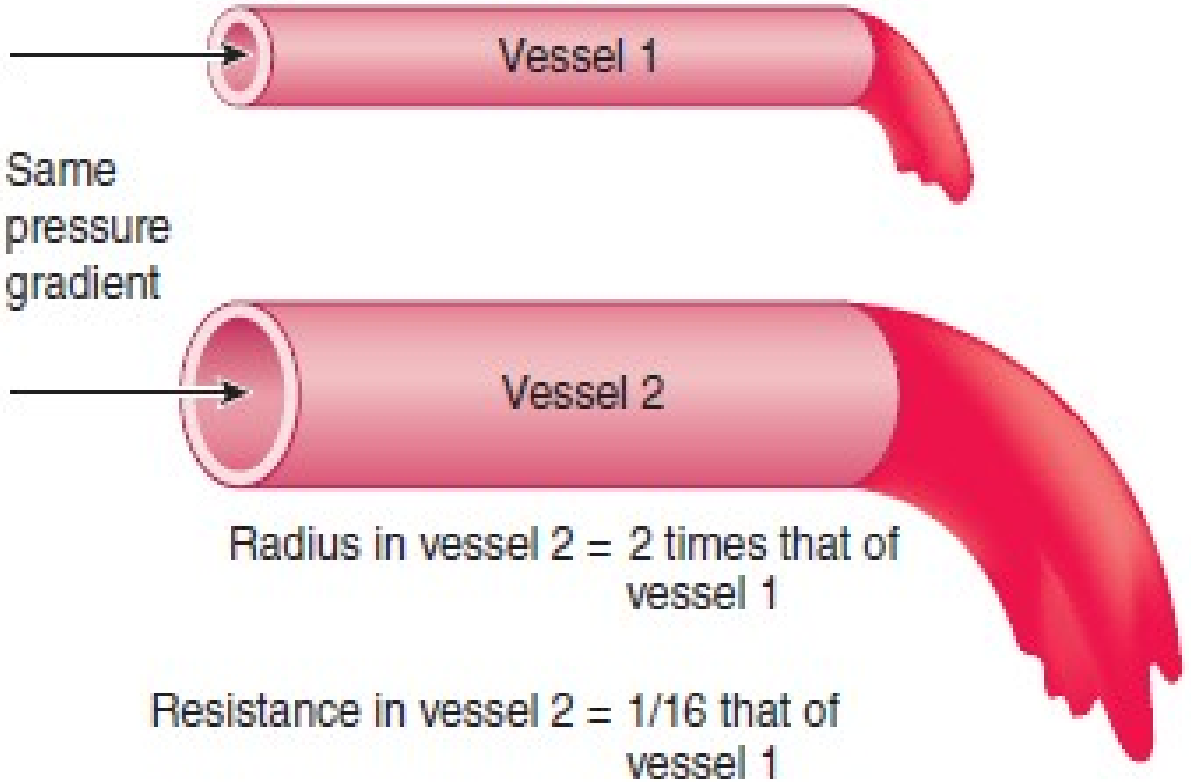
- Direct relation (length resistance)
- Vessel length don't change (NO effect on resistance)

2- Viscosity of the blood:

- Direct relation (viscosity resistance)
- Determinants:
  - 1- Hematocrit (VIP)
    - ♣ Only in large vessels (plasma skimming)
    - ♣ Polycythemia Vs. anemia
  - 2- Plasma proteins
    - ♣ Fibrinogen & globulin



(a) Comparison of contact of a given volume of blood with the surface area of a small-radius vessel and a large-radius vessel



Radius in vessel 2 = 2 times that of vessel 1

Resistance in vessel 2 = 1/16 that of vessel 1

Flow in vessel 2 = 16 times that of vessel 1

Resistance $\propto 1/r^4$
Flow $\propto r^4$

(b) Influence of vessel radius on resistance and flow

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Factors Affecting Resistance

3- Radius of the vessel:

- As the length of the vessel & viscosity of the blood is nearly constant change in the vessel diameter ***markedly*** ***affect the resistance***

- Indirect relation
- Resistance is inversely related to the radius

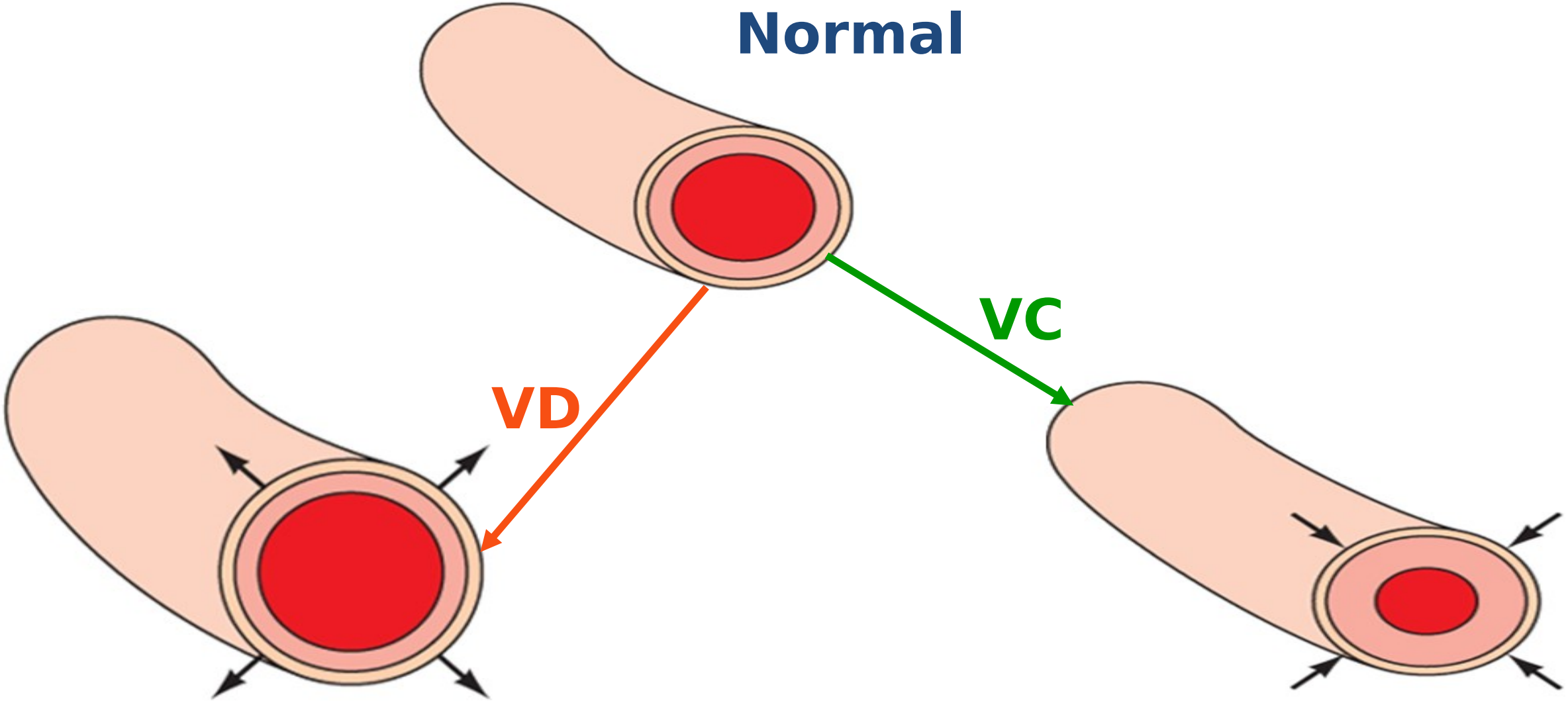
(radius resistance)

- ↑ radius = VD
- ↓ radius = VC

- Resistance is little in aorta & large branches
- Resistance is marked in smaller arteries (principally ***arterioles***)

- Radius is controlled by ***neuronal*** , hormonal & ***local factors***

Normal



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Relations between: Flow, Pressure & Resistance

Poiseuill's - Hagen formula

$$F = \frac{\Delta P \pi r^4}{8 \eta L}$$

ΔP : Pressure gradient

r^4 : Radius of the vessel to the fourth power

L : Length of the vessel

η : Viscosity of the blood

π : Constant (22 / 7)

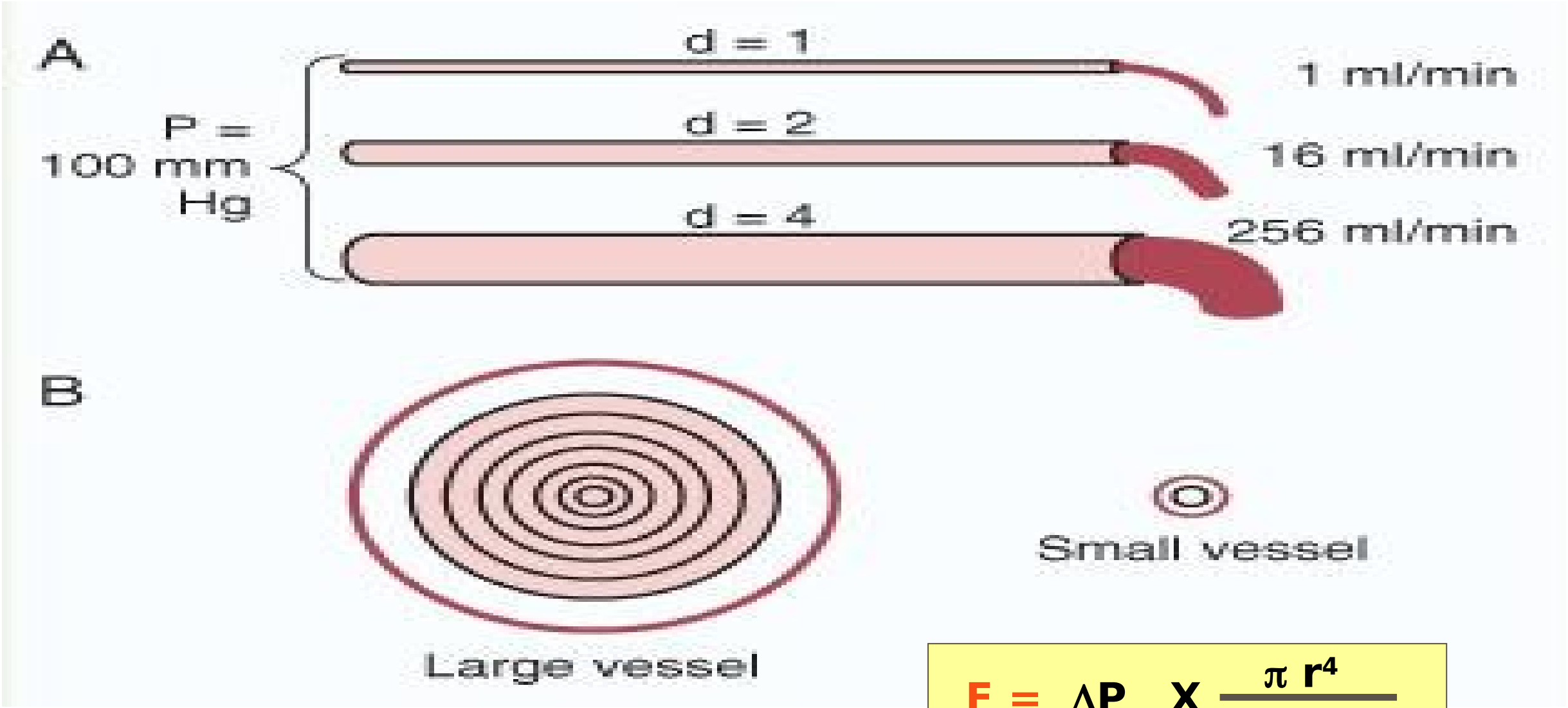
Relations between: Flow, Pressure & Resistance

Poiseuill's - Hagen formula

- **As the length of the vessel & viscosity of the blood is nearly constant change in the vessel *diameter* & *pressure gradient* affect blood flow *markedly***

♣ **Fourth power of radius**

 Slight changes in diameter of blood vessel have pronounced effect on the flow



$$F = \Delta P \times \frac{\pi r^4}{8 L \eta}$$

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Resistance

N.B

- **Resistance in the vascular system depends on the sum of the resistances in all blood vessels (TPR)**

- **VC anywhere □ □ TPR**

- **VD anywhere □ □ TPR**

SUMMARY

- The heart is a pressure generator.
- Blood flow is carefully regulated by controlling pressure gradient & resistance.
- Resistance to flow is determined by the physical properties of the tube as well as the fluid.
- Changes in the ***vessel diameter*** is main factor controlling blood flow.

Lecture Quiz

- **The resistance through blood vessels:**

a-Increases when the radius diameter is increased

b-Is directly proportional to the viscosity & length of the vessels

c-Is less in the systemic vessels than in pulmonary vessels

SUGGESTED TEXTBOOKS

1. **Guyton and Hall**
   Text book of Medical Physiology, 13th Edition (2016), Chapter 14 (**Overview of the Circulation; Biophysics of Pressure, Flow, and Resistance**)

2. **Ganong's**
   Review of Medical Physiology, 24rd Edition (2012), Chapter 31 (**Blood as a Circulatory Fluid & the Dynamics of Blood & Lymph Flow**)

3. **Fox**
   Human Physiology, 14th Edition (2016), Chapter 14 (**Cardiac Output, Blood Flow, and Blood Pressure**)

4. **Sherwood**
   Human Physiology .. From Cells to Systems, 9th Edition (2016), Chapter 10 (**The Blood Vessels and Blood Pressure**)


THANK YOU